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RESEARCH PAPER

Exploring Agrobiodiversity on Farm: A Case from Middle–Hills of Nepal

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Abstract A survey was conducted to examine agrobiodiversity status of farms in the Pokhare Khola watershed of Dhading district in the Middle-Hills of Nepal. A total of 53 farmland tree and one crop species from 22 families were documented. The most commonly found species were fruit and fodder species (on over 60 % farms) including banana (*Musa paradisiaca*), khasrato (*Ficus hispida*) and khanayo (*Ficus semicordata*). Tree density was highest (226/ha) on marginal farms (farm area ≤0.25 ha) and lowest (165/ha) on small farms (farm area 0.26–0.5 ha). For the study area as a whole, the Shannon-Wiener species diversity index was 3.26 and the species evenness index 1.89. Large farms (farm area >1 ha) had the greatest tree species diversity (4.47 ± 0.52) and marginal farms the lowest (2.18 ± 0.37), indicating the positive relationship between farm size and species diversity. A total of six types of cereals and 18 types of vegetable crops were grown in the study area. The major livestock component of each household was chickens (average 8/household) and goats (6/household). The mean value of livestock in the large farm category was estimated as $2235, significantly higher than that of the other three categories. A significant relationship was found between agrobiodiversity and

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livelihoods, irrespective of annual production, and the critical role of the farmed landscape in agrobiodiversity conservation was apparent.

Keywords Conservation · Diversity index · Forestry · Farm category · Hill farming

Agrobiodiversity and its Importance

Biodiversity is not only confined to forests, parks and other unmanaged or natural ecosystems but is also a feature of agricultural landscapes (Atta-Krah et al. 2004). Recently, 'agricultural diversity' as a scientific term has been widely accepted by both scientists and the public (Wood and Lenne 1999; CBD 2000; Hagmann and Muller 2001; Jarvis et al. 2001). CBD (2000) defined agrobiodiversity as all of the components of biological diversity relevant to food and agriculture, including agricultural ecosystems. Agrobiodiversity is a subset of biodiversity (Boef 2000), and therefore encompasses the variability of living organisms including trees, crops, animals, pollinators, pests, parasites, microorganisms, predators and in situ and *ex-situ* conservation at species, genetic, and ecosystem levels that are necessary to sustain agricultural production and the knowledge associated with them (CBD 2000; McNeely and Scherr 2003; Jackson et al. 2007). It refers to the human-managed or modified biological diversity in agro-ecosystems (Long et al. 2003). Accordingly, many studies have found greater biodiversity in human-managed ecosystems than in natural systems (e.g. Pimentel et al. 1992). Almekinders and Boef (2000) categorized agrobiodiversity into varietal or genetic diversity, crops, animals and other species diversity, and farming systems or other agro-ecosystem diversity.

Agricultural biodiversity (or agrobiodiversity) is the result of natural selection and human intervention over millennia, and has an essential role: in sustainable development for subsistence products including food, fuel and fodder; for sustaining ecosystem services such as watershed functions, soil health and pollination; for enabling species and ecosystems to evolve and adapt to climate change; and for providing genetic material for breeding new varieties, and offering socio-cultural, aesthetic and recreational values to people (CBD 2000). Thus, agrobiodiversity is regarded as a basis for sustainable food security and human survival (Wood and Lenne 1999) through increasing crop productivity while controlling diseases in the agroecosystems (Zhu et al. 2000).

Agricultural and forest productivity are reduced by climate change, drought, soil fertility loss, high evapotranspiration, increased insolation, delayed monsoons, and insects and pest attack (IPCC 2007; Regmi and Adhikari 2007; Rai 2008). Agricultural expansion has led to the reduction of forest land. Forests in Nepal provide fuelwood for 80 % of the population and 42 % of fodder for animals (FAO 1997), imposing pressure on forests (CBS 2006). For example, YingQiu et al. (2001) observed that all forest land in Chitwan will be depleted and replaced by agricultural land by 2030. Hill farmers have increasingly been confronted with a decline in forest fodder supply due to deforestation and livestock grazing in forests (Mahat 1987). Intensified agriculture on deforested land can be affected by

landslides and potentially glacial lake outburst floods (Chalise et al. 2006; SAGUN 2009). Therefore, there is increasing pressure to satisfy people's demand for forest products by increasing the tree component of farmed land (agroforestry). This can play a crucial role in the sustainability of agricultural production, reduction of pressure of remaining forests and enhancing agrobiodiversity through in situ conservation of trees on farms in the Middle–Hills of Nepal (Long et al. 2003; McNeely and Schroth 2006).

Modern agriculture is based on an increasingly restricted variety crops and animals. Half the energy intake from plants comes from only three species: wheat, rice and maize. In total, 90 % of the energy and protein in human food comes from only 15 plant and eight animal species (Sala et al. 2000). New plant and animal varieties and high-input agricultural systems have dramatically increased food output but have replaced many traditional agricultural products. In Nepal, modern varieties replaced landraces on three quarters of cultivated rice land between 1960 and 2000 (FAOSTAT 2006). One-fifth of the world's livestock breeds may be at risk from the intensification of farming as the global demand for meat and other animal products rises (FAO 2007).

Changes in land use, modern cropping patterns, over population, land degradation, over-harvesting of non-timber forest products (NTFPs), deforestation and habitat loss have severe impacts on agrobiodiversity, including on the wild relatives of crops. Climate change would also to speed the loss of agrobiodiversity as some areas become unsuitable for less tolerant varieties. Therefore, agrobiodiversity is now vulnerable at ecosystem, species, varietal and management system levels (Zhu et al. 2000; Upreti and Upreti 2002). Moreover, agrobiodiversity has never been widely integrated in agricultural adaptation strategies, which may create challenges in the future for sustainable production and enhancing ecosystem services depending on the management and farming techniques practiced (FAO 2008). Ecological experiments and modelling have shown that diversification of species composition could lead to enhancements of the stability and productivity of ecosystems (e.g. Chapin et al. 2000; Cottingham et al. 2001; Norberg et al. 2001; Tilman et al. 2001). Agrobiodiversity, therefore, should be emphasized by academic, economic, social and political sectors (Long et al. 2003).

Research Context

With population growth, increased food demand, climate change, and the globalization of agricultural markets during the next few decades, agricultural landscapes will undergo unparalleled transitions. About 75 % of the world's poor people live in rural landscapes, and are especially vulnerable to the ecological and economic risks associated with such transitions (WRI 2005). Therefore, new solutions are required for producing more food, fibre and NTFPs, for protecting the resource base upon which agriculture depends, and for promoting social wellbeing (MEA 2005). Conservation of existing biodiversity in agricultural landscapes and the adoption of agrobiodiversity-based practices have been proposed as ways to increase the sustainability of agricultural production, whilst conserving forests. In the Millennium Ecosystem Assessment (MEA 2005), biodiversity is mentioned as

an important coping strategy against agricultural risks in an uncertain future (Wood and Lenne 2005).

The complementary relationship of crop, livestock and tree components to fulfill the livelihood needs of resource-poor farmers and maintain ecological stability is paramount in the 'Nepalese Hill Farming System' (Neupane and Thapa 2001; Maharjan 2005), which offers the greatest ecosystem and species diversity in the Middle-Hills among the five physiographic zones of Nepal (HMGN 2002). However, warming in Nepal has been much more pronounced in the Middle-Hills and the high Himalaya than in the Terai and Siwalik regions (Kansakar et al. 2004; Dahal 2005). This is also where the population density is highest and consequently where vulnerability to climate change is most pronounced. Therefore, poor, marginalized and disadvantaged people are less resilient to climate variability (Dahal 2006; Regmi and Adhikari 2007). Fragile livelihoods and the vulnerability of hill biodiversity have highlighted the necessity for an assessment of agrobiodiversity status in the farmland of the Middle-Hills of Nepal.

Conservation of agrobiodiversity is a prerequisite to maintain agroecological services (Boef 2000). Conservation of agricultural diversity in Nepal is based on diverse farming systems built upon indigenous knowledge, innovations and experiences (Upreti and Upreti 2002; Rasaily 2006) adapted by farmers for generations (Dahal 2006; Regmi and Adhikari 2007). Thus, farmers with traditional farming systems incorporating in situ conservation (diversity, integration, conservation) are contributing to agrobiodiversity (Upreti and Upreti 2002). Indigenous in situ conservation of agrobiodiversity is strength of Nepalese agriculture, which maintains crop and species diversity and conserves genetic resources (Upreti 2000). Though numerous papers have revealed the importance of in situ conservation of agrobiodiversity (e. g. Zhou 2000; Zhu et al. 2000), much still needs to be learned about the status of agrobiodiversity as natural capital for providing food, goods and services for agriculture, and the direct and indirect use value in economic terms that are derived from these goods and services (Swift et al. 2004). Natural capital (forests, agricultural land, grassland) is strongly associated with agrobiodiversity, upon which people's livelihoods depend (Regmi 2003; Sharma and Tsering 2009; Baul 2010). To reduce the pressure on forests and sustain the agricultural production, planting trees and new crop varieties on farms is required. For this reason society will need to invest more in agrobiodiversity research for both utilization and conservation of agrobiodiversity.

Agrobiodiversity status is essential baseline information for conservation policy in order to promote agrobiodiversity based on utilization and conservation in agricultural landscapes in Nepal. Therefore, this study aims at exploring the existing status of agrobiodiversity in terms of tree species, crop and livestock in agricultural landscape of Middle-Hills of Nepal.

The Study Site

The study site is located about 60 km west of the Kathmandu. Geographically, it lies between 27°46′28″N and 27°48′06″N latitude and 84°53′32″E and 84^{0}55′11″E longitude (CBS 2006). The Pokhare Khola watershed lies in Pida village of Dhading

district in the Central Middle-Hills of Nepal from 400 m in the valley bottom to 800 m on the hill slopes which represents the 'middle mountain farming system' (Fig. 1). The climate is sub-tropical with mean monthly temperature ranging from 13 to 27° C, mean monthly rainfall from 7 to 341 mm and average annual rainfall 1,699 mm, more than 80 % of which occurs from June to September as recorded at the nearest meteorological station of Dhunibeshi 30 km away. There are three distinct seasons: rainy (wet), winter, and hot or humid summer (Tiwari 2008). Cambisols and Luvisols make up the dominant soils in the study area (Tiwari et al. 2006) and the terrain is steeply sloping.

The major land uses in the study area are forestry and agriculture. Forest land covers about 55 % of the watershed area and is an integral part of the farming system. Two main cultivation systems are *khet*, which covers about 10 %, and *bari* 35 % of the watershed area. The *khet* land consists of bounded and leveled terraces, which are generally located near streams away from households. Bari land includes *bari* (around the homestead areas) and *pakhabari* (separate plots up to 30 min walking distance) (Pratap 2004; Tiwari et al. 2006). This farming system includes trees, crops and livestock, providing a source of both food and bedding (tree fodder

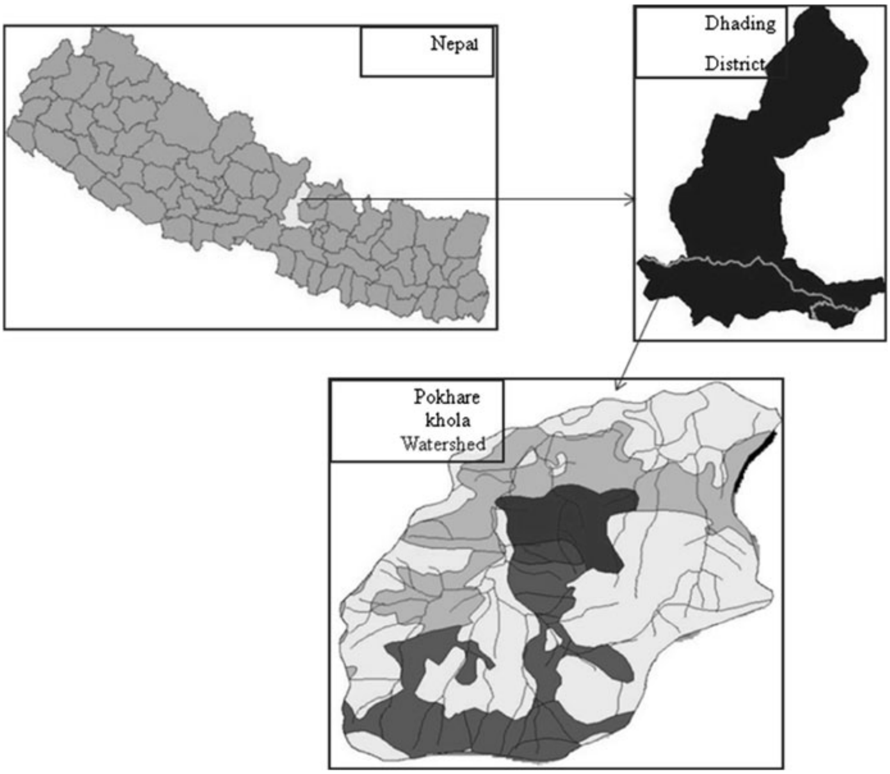

Fig. 1 Location map of Pokhare Khola watershed of Middle-Hill of Dhading district in Nepal *Source*: Tiwari (2008)

and grasses) for livestock, compost materials to improve soil fertility, and fuelwood and timber for household use.

Research Method

A survey was conducted, stratified by villages at various altitudes (all over 400 m and six at 600 m and higher). Eight villages in Wards 2 and 3 in the Pokhare Khola watershed were selected, with random sampling of farm households within villages. A total of 148 farm households were selected, from 340 households. The head of the selected households (assumed to be the decision-maker in farming) or their spouse was interviewed. Sample households of each village were selected proportionately according to the number of total households, supplied by village development committee (VDC) offices. Two trained enumerators conducted personal interviews. Data were collected on tree species and their uses, cereal and vegetables crop species with annual production, number of individuals within livestock species and their value, and area of farm land. The number of individual trees by species was counted on sampled farms with the help of the farm owner. Interviews were also conducted of key informants including community forest user group members, village chiefs, VDC officials, experienced farmers, teachers and villagers who had migrated from other areas.

Farms were categorized into four groups—marginal, small, medium and large—based on the area of farmland owned (Table 1). The definition of farm sizes was agreed with the farmers during the survey.

Species Diversity Assessment

Species composition, density, frequency, abundance, richness and evenness are important characteristics for classifying agrobiodiversity status. Abundance is the number of each individuals of each species in the site, richness denotes the total number of species in an area and diversity has two components which stand for both species richness and species evenness, i.e. how well abundance is distributed among species within a community (Wilsey and Polley 2002; Debano 2006).

Species diversity was calculated using the Shannon-Wiener index (Michael 1990; Southwood and Henderson 2000). Species diversity has been considered as a vital

Table 1 Household categories based on the area of farm

Farm category	Farm area in ropani[a]	Farm area (ha)
Category 1 (marginal farm)	Equal or less than 5 ropani	≤0.25 ha
Category 2 (small farm)	6–10 ropani	0.26–0.5 ha
Category 3 (medium farm)	11–20 ropani	0.51–1 ha
Category 4 (large farm)	More than 20 ropani	>1 ha

[a] 20 Ropani = 1 ha

parameter for ecological stability and livelihood security. According to Magurran (1988), diversity indices typically lie between 1.5 to 3.5 and in some cases can exceed 4.5. Tree density was measured by number of trees per unit area of *bari.* Species evenness index, frequency of occurrence, relative density and absolute density were also calculated as follows:

i. Frequency of occurrence of tree species = Total number of farms in which tree species occur $\times$100/Total number of farms studies.
ii. Relative density of a species = Total number of individual of a species in all farms $\times$100/Total number of individual of all species.
iii. The Shannon-Wiener index for diversity,

$$H = -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where p_i = Number of individual of one species/Total number of individuals in the farms, and S = Total number of species.

iv. Species evenness index, E = H/log S

where H = Shanon-Wiener index of diversity.

v. Trees density (tree number/ha) = Total number of individuals of all species on a farm/Area of that farm (ha)

Spearman's correlation coefficient was derived to check for association between farm size and species diversity and species evenness. Kruskal–Wallis tests were conducted to test the significance of SDI, evenness, tree density (tree number/ha) and mean livestock value between different farm categories.

Results

A total of 53 tree and one crop species of 22 families including fodder, fruits, and multipurpose tree species (MPTS) were found on landholdings in the study site, out of which, the family Moraceae was represented by highest (eight) species, followed by Rutaceae with seven species, Leguminosae with five species (Table 2).

A number of species were found on most properties sampled. Among these, banana (*Musa* spp.), khasreto (*Ficus hispida*) and khanayo (*Ficus semicordata*) were the most commonly found species (each found on over 60 % of surveyed farms). Of the most abundant 10 species, all were fodder tree species except one fruit (banana) and one multipurpose species (Sal, *Shorea robusta*) indicating the importance of fodder species to the farmers (Table 2; Fig. 2).

Relative density of a species indicates the percentage of total number of individual of that species among those of all species in an area. The relative density was highest for *Musa paradisiaca* (20.94 %) followed by *Shorea robusta* (17.26 %) (Table 2). The mean tree density for the whole study area was 188.09 $\pm$ 15.58 with the highest density (226/ha) on marginal farms and lowest density (165/ha) in the

Table 2 Tree species planted on farms and their uses, occurence and density

Local name	English name	Scientific name	Family	Major uses	Frequency (%)	Relative density
Aaru	Peach	*Amygdalus persica*	Rosaceae	Fruits	16.89	0.45
Aarubhakhada		*Amygdalus species*	Rosaceae	Fruits	0.68	0.01
Amala	Embric Myrobalan	*Phyllanthus emblica*	Euphorbiaceae	Fruits	0.68	0.02
Amba	Guava	*Psidium guajava*	Myrtaceae	Fruits	20.27	0.85
Anar	Apple Grante	*Punica granatum*	Punicaceae	Fruits	0.68	0.08
Badahar	Monkey jack	*Artocarpus lakoocha*	Moraceae	Fodder/timber/ Fruit	2.70	0.09
Bakaino	China-Berry	*Melia azederach*	Meliaceae	Fodder/firewood	4.73	0.46
Bakhre	Pink Bauhinia	*Desmodium multiflorum*	Leguminosae	Fodder	8.11	0.97
Barro	Belleric Myrobalan	*Terminalia belirica*	Combretaceae	Fodder	4.05	0.12
Bans	Bamboo	*Dendrocalamus strictus*		Other	1.35	1.14
Bhogate	Melon fruit	*Citrus maxima*	Rutaceae	Fruits	0.68	0.01
Birali		*Ficus subincisa*		Fodder	1.35	0.07
Chasme	Grape fruit	*Citrus paradisi*	Rutaceae	Fruits	0.68	0.01
Chilaune	Needle wood	*Schima wallichi*	Theaceae	Timber/firewood	6.76	6.68
Dabdabe		*Garguawa pinnata*	Euphorbiaceae	Fodder	0.68	0.04
Gayo		*Bridelia restusa*		Fodder	35.14	3.48
Gedulo		*Ficus clavata*	Verbenaceae	Fodder	1.35	0.05
Gindari	Headache Free tree	*Premna integrifolia*	Euphorbiaceae	Fodder	4.73	0.18
Harro	Chebulie Myrobalan	*Terminalia chebula*	Combretace	Fodder	2.70	0.10
Ipil–Ipil		*Leucaena leucocephala*	Leguminosae	Fodder	47.30	5.73
Kabro		*Ficus lacor*	Moraceae	Fodder	52.03	2.92
Kagati	Lime	*Citrus aurantifolia*	Rutaceae	Fruits/Medicine	0.68	0.01
Katahar	Jack Fruit	*Artocarpus heterophyllus*	Moraceae	Fruits/Timber	22.30	0.61
Bar	Banya Tree	*Ficus benghalensis*	Moraceae	Fodder	10.14	2.10
Kera	Banana	*Musa paradisiaca*	Musaceae	Fruits	71.62	20.95
Khanayo		*Ficus semicordata*	Moraceae	Fodder	62.16	7.08
Khasreto		*Ficus hispida*	Moraceae	Fodder	62.84	8.94
Kimbu	Mulberry	*Morus alba*	Moraceae	Fodder	39.86	9.20

Table 2 continued

Local name	English name	Scientific name	Family	Major uses	Frequency (%)	Relative density
Kutmero		*Litsea monopetala*	Lauraceae	Fodder	27.70	2.53
Lapsi	Nepalese Hogplum	*Choerospondias axillaris*	Anacardiaceae	Fruits/Fodder	1.35	0.08
Litchi	Litchi	*Litchi chinensis*	Sapinadaceae	Fruits	17.57	0.52
Local Anp	Mango	*Magnifer indica*	Anacardiaceae	Fruits/Fodder/Firewood	27.70	0.97
Mewa	Papaya	*Carica papaya*	Caricaceae	Fruits	6.76	0.45
Naspati	Pears	*Pyrus communis*	Rosaceae	Fruits	15.54	0.39
Nibuwa	Lemon	*Citrus limon*	Rutaceae	Fruits	4.05	0.12
Nim	Neem Tree	*Azadirachta indica*	Meliaceae	Medicine/Fodder	0.68	0.01
Niwaro		*Ficus auriculata*	Moraceae	Fodder	0.68	0.02
Padake		*Carpenslum nepalense*	Papaveraceae	Timber/Firewood	0.68	0.19
Padari		*Stereospermum personatum*	Bignoniaceae	Fodder	2.70	0.15
Phaledo		*Erythrina arborescens*	Leguminosae	Fodder	0.01	0.02
Phandir	Indian Black Berry	*Syzygium cumini*	Myrtaceae	Fruits	0.68	0.05
Firfire		*Acer oblongum*	Aceraceae	Fodder	2.03	0.03
Pipal		*Ficus religiosa*	Bignoniaceae	Fodder/Religious(Other)	11.49	0.30
Saj	Lourel Tree	*Terminalia alata*	Combretaceae	Timber/Fodder	0.68	0.03
Sal		*Shorea robusta*	Dipterocarpaceae	Timber/Fodder/Religious	35.81	17.27
Sindure		*Bixa orelana*	Bixaceae	Fodder	1.35	0.02
Sissoo	Sissoo Redwood	*Dalbergia sissoo*	Leguminosae	Fodder	0.68	0.02
Sisnu		*Urtica dioca*		Other	0.68	0.01
Tanki	Pink Bauhinia	*Bauhinia purpurea*	Leguminosae	Fodder	40.54	3.03
Tuni	Cedrela Tree	*Toona ciliata*	Meliaceae	Fodder	0.68	0.02
Dumri		*Ficus benjamina*		Fodder	23.65	1.36
Chaksi	Sweet Lime	*Citrus limettioides*	Rutaceae	Fruit	0.68	0.03
Mausam	Sweet orange	*Citrus sinensis*	Rutaceae	Fruit	0.68	0.01
Suntala	Mandarin	*Citrus reticulata*	Rutaceae	Fruit	2.03	0.05

small farm category. Farmers with medium sized farms showed similar tendency in planting trees as marginal farmers (Fig. 3). However, the difference of tree density was not significant between farm categories.

Fig. 2 Fodder tree species and cereal (maize) in *bari* land

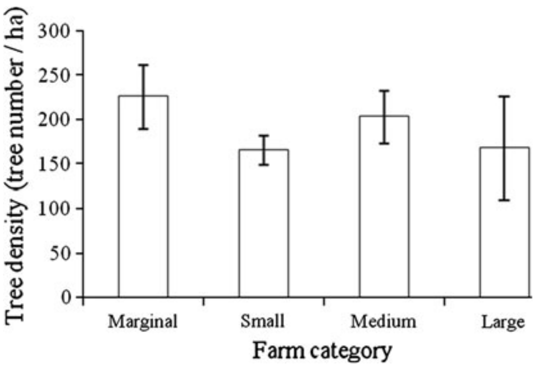

Fig. 3 Distribution of planting density of trees in *bari* land under each farm (sph). *Bars* represent ± one standard error

Table 3 Shannon-Wiener index (H), evenness index of species (E) and mean livestock value (NR) by farm category

Farm category	Shannon-Wiener index (H)	Species evenness (E)	Livestock value (NR[a]) mean ± standard error
Category 1 (marginal farm)	2.18 ± 0.37	1.26 ± 0.21	94,981 ± 13,737
Category 2 (small farm)	2.86 ± 0.14	1.65 ± 0.08	116,925 ± 7,282
Category 3 (medium farm)	3.63 ± 0.16	2.10 ± 0.09	138,197 ± 5,515
Category 4 (large farm)	4.47 ± 0.52	2.58 ± 0.30	160,914 ± 16,182

[a] 72 Nepali Rupee (NR) = 1$ as at 30 July 2010

Generally, SDI measured was 3.26 ± 0.12 and species evenness index was 1.89 ± 0.07. There was a strong positive correlation between actual farm size and the species diversity (Spearman′s rho = 0.417, n = 148, $p \leq 0.01$) indicating the larger the area of farm, the higher the species diversity. There was a significant difference ($p < 0.01$) of SDI among farm categories with the larger farms having the greatest diversity (4.47 ± 0.52) and evenness (2.58 ± 0.30) of species while the

Fig. 4 Vegetables farming in *bari*

Fig. 5 Paddy cultivation in *khet*

marginal farms had the lowest diversity (2.18 ± 0.37) and evenness of species (1.26 ± 0.21) (Table 3).

Bari and *khet* lands are used for cultivation of cereal and vegetables crops (Figs. 4, 5). *Khet* is the most valuable land because it can produce two major crops annually (rice and wheat) when irrigated. *Bari* land consists of sloped, rain fed terraces in which maize and millet are grown. The *bari* land has also been used intensively for growing several species of seasonal vegetables for domestic and commercial purposes all year round. According to respondents, *kharbari* land is set aside for grass production for roofing thatch and livestock feed.

A total of six species of cereal crops—rice (*Oryza sativa*), wheat (*Zea maize*), maize (*Triticum aestivum*), millet (*Elusine coracana*), soya bean (*Glycine max*) and mustard (*Brassica* sp.)—were grown in study area. Rice and maize were grown by almost all farmers. Among 18 types of vegetables found, some principal crops—including cauliflowers (*Brassica oleracea*), beans (*Pheseolus vulgaris*), bitter gourd, gourd (*Cucurbita pepo*), brinjal (*Solanum melongena*)—were cultivated by most of the farmers. Mean annual production of rice and maize among all cereal crops, and

Table 4 Cereal and vegetables crop species grown on farm land

Crop type	Common name	English name	Scientific name
Cereal	Rice	Rice	*Oryza sativa*
	Maize	Maize	*Zea maize*
	Wheat	Wheat	*Triticum aestivum*
	Millet	Millet	*Elusine coracana*
	Mustard	Mustard	*Brassica* sp.
	Soybean	Soybean	*Glycine max*
Vegetables	Potato	Potato	*Solanum tuberosum*
	Cauliflower	Cauliflower	*Brassica oleracea* var. *Botrytis*
	Cabbage	Cabbage	*Brassica oleracea* var. *Capitata*
	Gourd	Gourd	*Cucurbita pepo*
	Karela	Bitter gourd	*Momordica charantia*
	Lady's finger	lady's finger	*Abelmoschus esculentus*
	Tomato	Tomato	*Lycopersicon esculentum*
	Brinjal	Brinjal/Aubergine/Eggplant	*Solanum melongena*
	Bean	Bean	*Pheseolus vulgaris*
	Cucumber	Cucumber	*Cucumis sativus*
	Chilli	Chilli	*Capsicum annum*
	Capsicum	Capsicum	*Capsicum frutescens*
	Pumpkin	Pumpkin	*Cucurbita pepo*
	Spinach	Spinach	*Spinacia oleracea*
	Pineapple	Pineapple	*Ananas comosus*
	Chacinga (Ghiraula)	Snack gourd	*Trichosanthes anguina*
	Pea	Pea	*Vigna sinensis*
	Onion	Onion	*Allium cepa*

all the vegetables crops grown in almost all types of farms, were the highest (Tables 4, 5, 6, 7).

The mean value of livestock in the large farm category estimated as \$2235[1] varied significantly from that of the other three farm categories ($p \leq 0.001$), Table 3). Farmers rear the highest number of chickens (8/household), goats (6/household) and lowest number of buffaloes with irrespective of farm category (Fig. 6). In general, large livestock appeared as available in smaller number in the study area.

Discussion

The observed diversity of tree species in this farming system plays a significant role in the in situ conservation of biodiversity that also supplies subsistence materials in the rural households of the Middle-Hills of Nepal. These findings are consistent with

[1] 72 NR = 1 \$, Date of relevance : 30 July 2010.

Table 5 Mean production of cereal crops under various categories of farm (kg/year)

Farm category	Maize	Rice	Soyabean	Millet	Wheat	Mustard	Average cereal production
Marginal	380.63	406.25	0.88	75.00	21.88	2.19	886.81
Small	573.04	654.46	0.19	129.91	59.06	43.88	1,460.54
Medium	824.03	1,369.03	0.48	152.02	56.45	44.60	2,527.26
Large	1,352.14	2,060.71	3.79	260.71	115.00	17.50	3,809.86

Table 6 Mean production of vegetables in various categories of farm (kg/year)

Farm category	Bean	Cauli-flower	Cabbage	Tomato	Onion	Bitter gourd	Brinjal	Gourd	Chilli
Marginal	62.25	982.50	381.25	37.50	12.50	343.75	162.50	206.25	125.00
Small	199.20	550.54	46.43	129.73	3.57	612.50	166.07	323.57	87.68
Medium	238.06	1,215.16	162.10	218.55	16.94	842.10	318.55	387.42	164.52
Large	264.29	992.86	185.71	178.57	7.14	635.71	178.57	650.00	85.71
Total	206.83	917.50	144.26	161.59	10.47	681.82	230.74	368.51	123.72

Table 7 Mean production of vegetables in various categories of farm (kg/year)

Farm category	Cucumber	Peas	Potatoes	Capsicum	Lady′s finger	Ghiraula	Pumpkins	Pineapples	Spinach
Marginal	0.00	0.00	14.00	0.00	6.88	75.00	0.00	0.00	0.00
Small	10.71	1.79	104.46	0.00	7.50	103.57	178.57	3.57	0.00
Medium	160.48	1.61	108.06	16.45	132.26	262.90	48.39	0.00	0.32
Large	71.43	0.00	71.43	0.00	113.57	285.71	0.00	0.00	0.00
Total	78.04	1.35	93.07	6.89	69.73	184.46	87.84	1.35	0.14

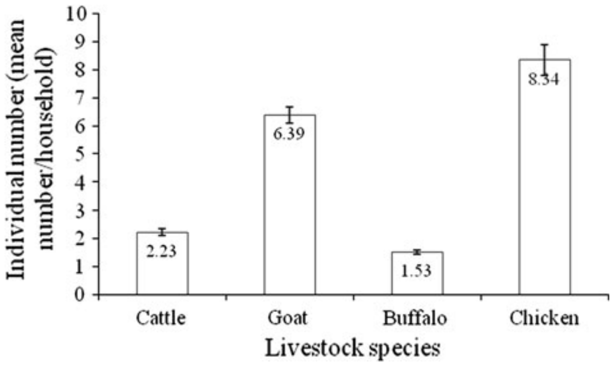

Fig. 6 Status of livestock species (number/household). *Bars* represent ± SE

Fonzen and Oberholzer (1984) where 53 perennial species in similar subsistence farming areas in the Western Hills were recorded, while Rusten (1989) and (Acharya et al. 2004) recorded 153 species including vines in the Middle–Hills and133 plant species in two village development committee (VDCs) of Parbat district in the Western Middle-Hills of Nepal, respectively. Another study conducted in the Central Hills of Nepal (Carter and Gilmour 1989) found only 29 farm trees species and in the Eastern and Central Terai regions (Das 1999; Kharal 2000) 60 species of plants on farms were evident. Like other studies, increased tree species in farms in the Middle-Hills had an important role in floral in situ conservation (Mcneely and Schroth 2006), and hence a reduction of pressure of remaining forests.

As for fruit species (*M. paradisiaca*) on *bari* land in this area, other studies also showed the highest frequency for *Mangifera indica,* a fruit species in homegardens of Bangladesh (e. g. Alamgir et al. 2000; Sarkar 2002). This might be a sign of preference of fruit and fodder trees to be cultivated by farmers around households, as also reported by Duguma et al. (2001), Sonwa et al. (2001) and Asare (2006) to secure their demand of daily necessities of fruits and fodder.

Trees were counted only on *bari* land, because *khet* was only used for agricultural crops that permitted the presence of only 2 % of total trees in *khet*. The findings of overall tree density (188 trees/ha) in Middle-Hills coincide with Bernholt et al. (2009), where the density of perennial species was the highest, resulting in a species rich top layer of hill. On the other hand, this study is disagreement with Oke and Odebiyi (2007), where lower density was found in some other farming systems. The reason why marginal farms in this study had high tree density may be that farmers with smaller *bari* land are more dependent on the *bari* for all their domestic needs of tree products, and therefore maintaining high tree density by close spacing within a small farm area is a component of their livelihood strategy. A similar observation was also made by Southern (1994) for the Kandy homegardens of Sri Lanka. Kumar et al. (1994) found that density was greater in small gardens (<0.4 ha) than in medium (0.4–2.0 ha) and large (>2.0 ha) areas. However, irrespective of farm category, a reduction of trees in forest is compensated by the increased number of trees on farms (Jianchu 2009), which strengthens conservation of agrobiodiversity on farm.

Although diversity is often equated with species richness, diversity is a function of the number of species and the evenness in distribution of species' abundances (Magurran 1988; Purvis and Hector 2000). The significant difference in tree species diversity and evenness among farm categories is in agreement with Gautam (1986) and Malla and Fisher (1988) and differs from Acharya (2006) where farmers with medium land area had greater tree species diversity. Shannon's index (3.26) for this study site is consistent with the findings of Bashar (1999) for homegardens of Bangladesh (3.24) and is greater than in cocoa agroforests (2.71) (reported by Oke and Odebiyi 2007), or the farming system (2.91) of Parbat where the SDI was calculated using shrub and grass species (Acharya 2006). By contrast, unsurprisingly a lower diversity with respect to that of natural forest (3.58) (reported by Oke and Odebiyi 2007), or homegardens in Sri Lanka (3.93) (reported by Kharal 2000) was documented in this study. A study in Bangladesh by Millat-e-Mustafa (1997) found the Shannon-Wiener index for tree species in homegardens of 3.33.

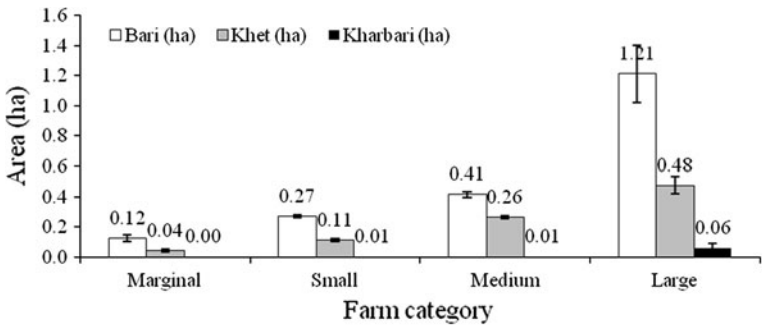

Fig. 7 Mean area of *bari*, *khet* and *kharbari* under different categories of farms. *Bars* represent ± SE

The high diversity of cereals and vegetables contributes directly to agrobiodiversity conservation and livelihoods. This is consistent with Soemarwoto and Conway (1992) and Shrestha et al. (2002) in thethat farmers cultivate a higher diversity of crops at higher elevations. Small livestock and particularly chickens are a major component of farmer livelihoods as also observed by Alam and Masum (2005) in homesteads of Bangladesh, and by Schroth and Harvey (2007) in agroforestry farms of Latin America, Africa and Asia. Higher value large livestock (cattle, buffaloes) or larger numbers of small livestock, such as goats, are constrained by fodder and water shortages and lack of time for large livestock husbandry which *bari* farmers could manage and supply from their greater tree density (Fig. 7; Key informant interview).

Conclusions

In Nepalese Middle-Hill farming systems a total of 53 tree species, and one fruit (banana) and one fodder species, and high crop diversity, play an important role in in situ conservation of biodiversity that supplies the basic and multipurpose materials for rural households. Through this research, it has become clear that farm area and species diversity are positively correlated. Large and medium farms have the larger *khet* and *bari*, and highest production value of livestock. Thus, the land-use system of the Middle-Hills involves deliberate management of cereals and vegetables and of trees, grass and livestock. Thus introduction of new crops and trees, and goat keeping as a new form animal husbandry, has provided increased resilience to changing climate. Facing future trends of climate change, and increasing environmental uncertainty, there is a clear and timely window for more research on agrobiodiversity in terms of conserving genetic diversity and providing ecosystem services. This can offer a platform for agrobiodiversity conservation in hill farming systems through agroforestry in situ, for sustainable agriculture, and for protection of natural forest. Because local people are the managers of natural resources and ‘agrobiodiversity’, they should be engaged in the management at local, regional and national level in securing and conserving biodiversity in the agricultural landscape. Agricultural scientists are also not adequately familiar with

the issues of biodiversity and agrobiodiversity. There should be increased efforts at studying species diversity (with respect to crops, trees and livestock) and the driving forces of what people prefer, whether in existing farming systems or in terms of potential new crops. Agricultural scientists and forest scientists must be made aware of the policy and legislation aspects of on-farm biodiversity, and be encouraged to be involved in the development of policies that will promote the wize use, management and legal aspects of species diversity.

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